

What Every Operator should know about Process Efficiencies:

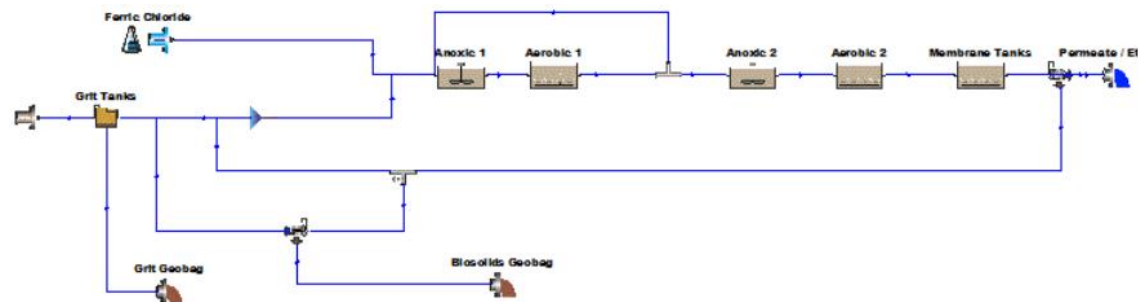
38th Annual MWOA Conference

Presented by: Corey Bjornberg
City of Rochester



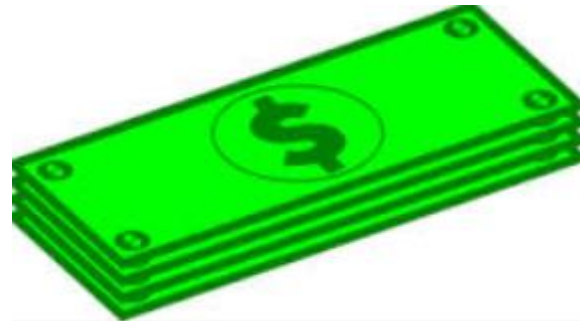
Presentation Outline

- Why should we care about Process Efficiencies?
- A quick overview of the Rochester WRP plant.
- Aeration
- Chemicals
- Mixing
- Solids
- Sidestreams



Why Should we Care about Process Efficiency

- Economics (all comes down to the money)
- Stable Process (reduce stress on operator's)
- Optimization of Current System (do more with less)
- Consideration for future expansion (delay, reduce expansion)
- Continue to meet compliance and more (going above and beyond)



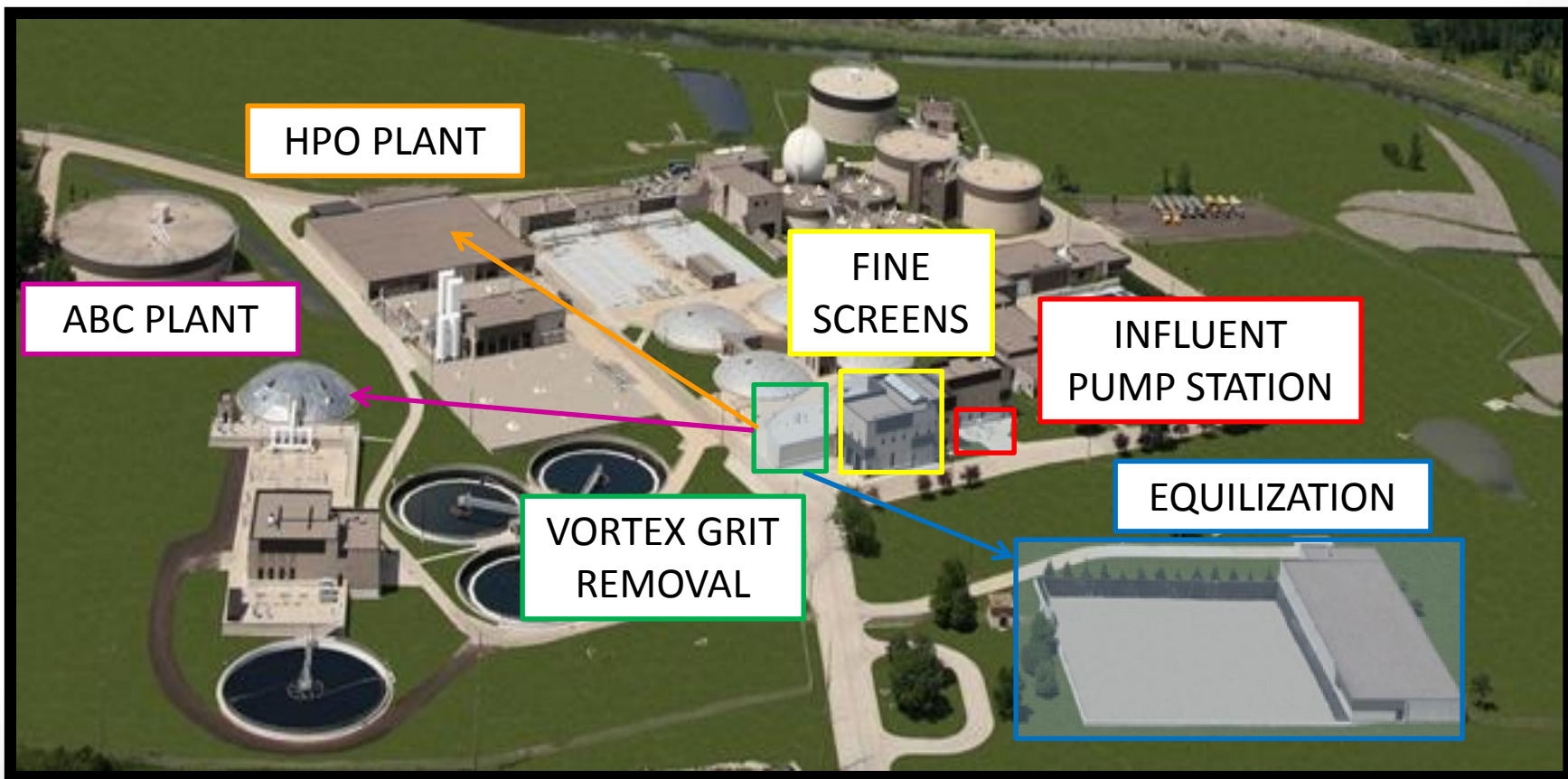
Rochester WRP Facility

- Treat 14 million gallons per day of wastewater
- 2 Plants – High Purity Oxygen & Conventional Air



Rochester WRP Facility

Headworks



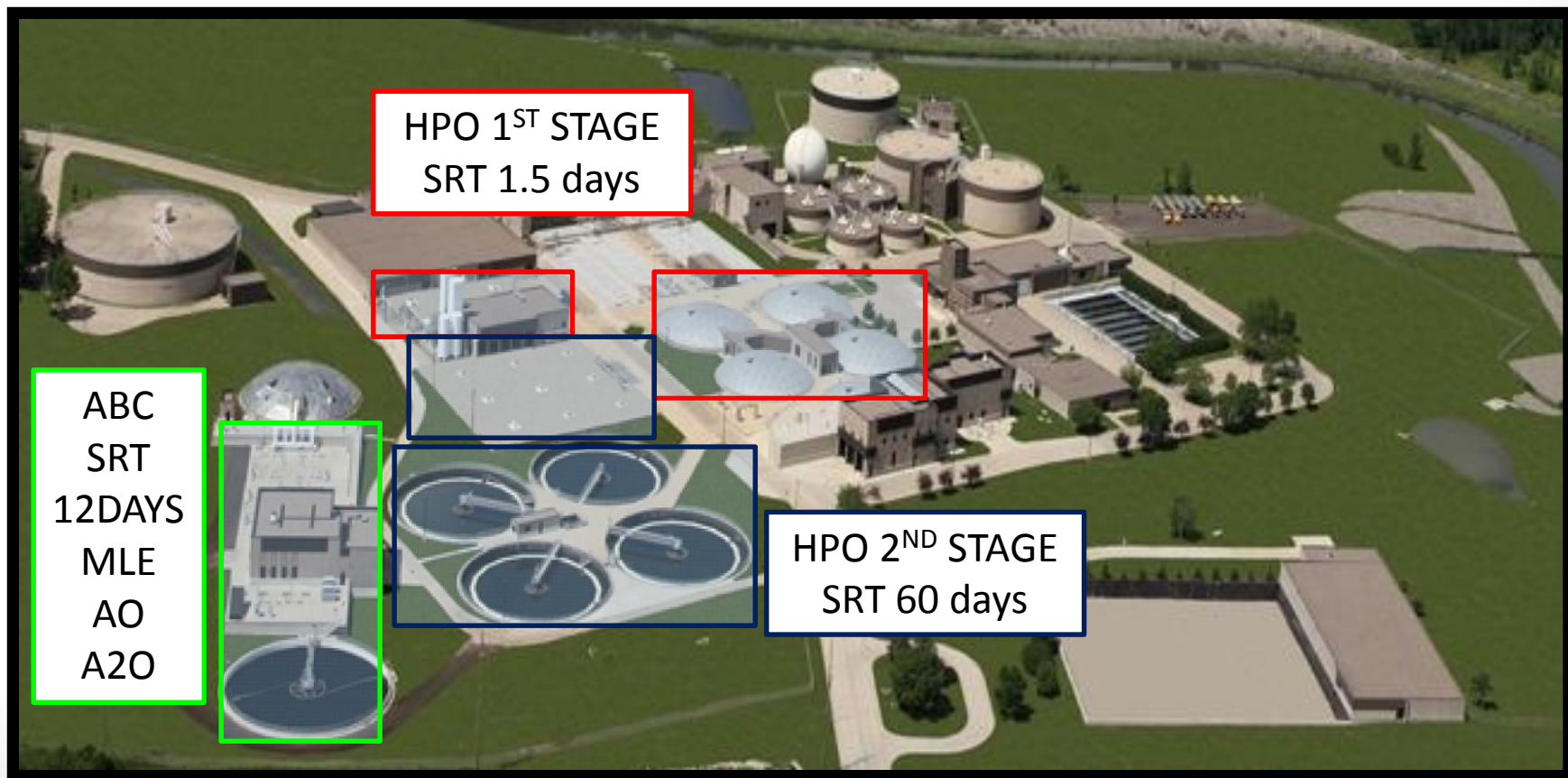
Rochester WRP Facility

Primary Treatment



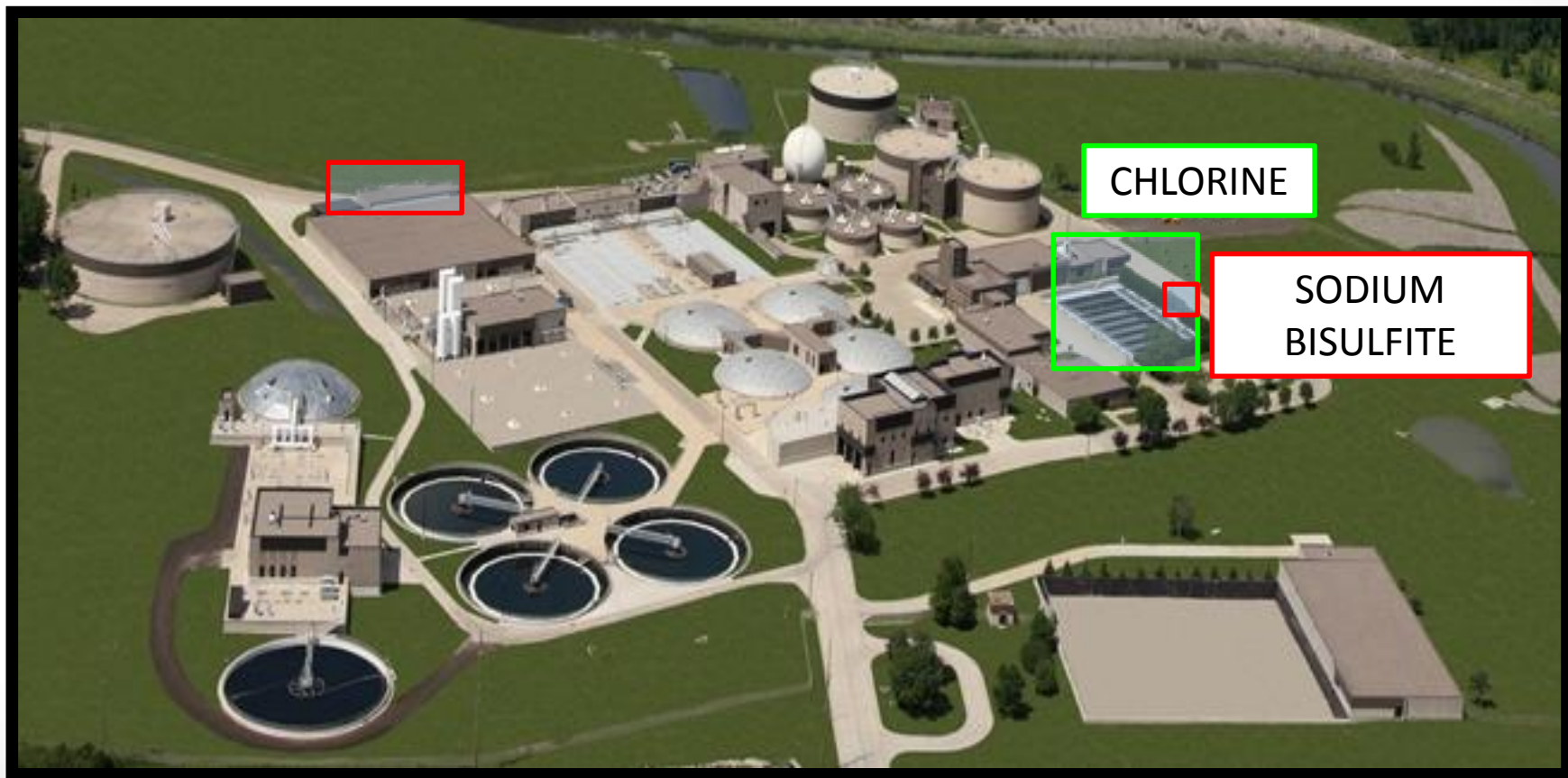
Rochester WRP Facility

Secondary Treatment



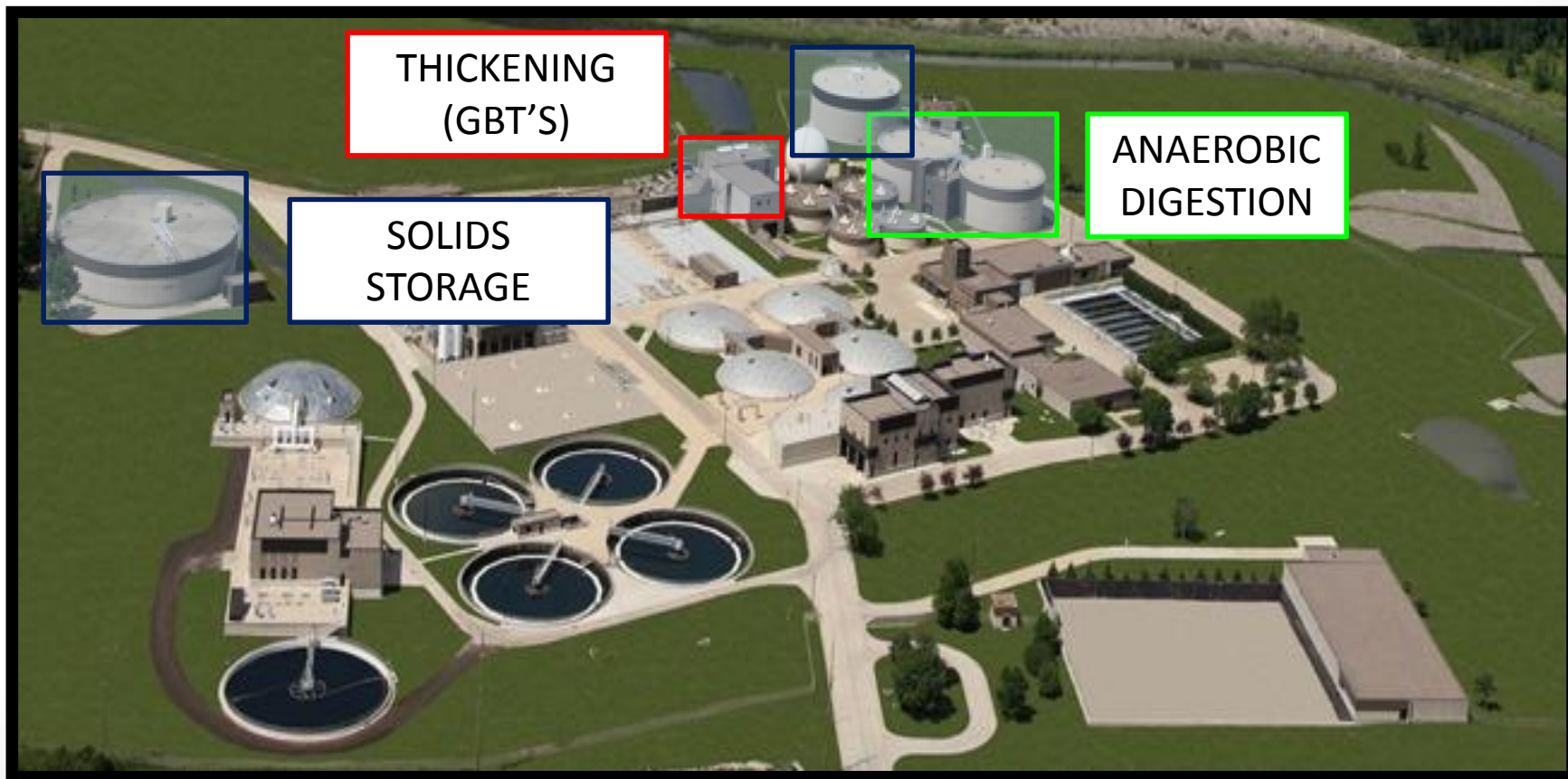
Rochester WRP Facility

Disinfection



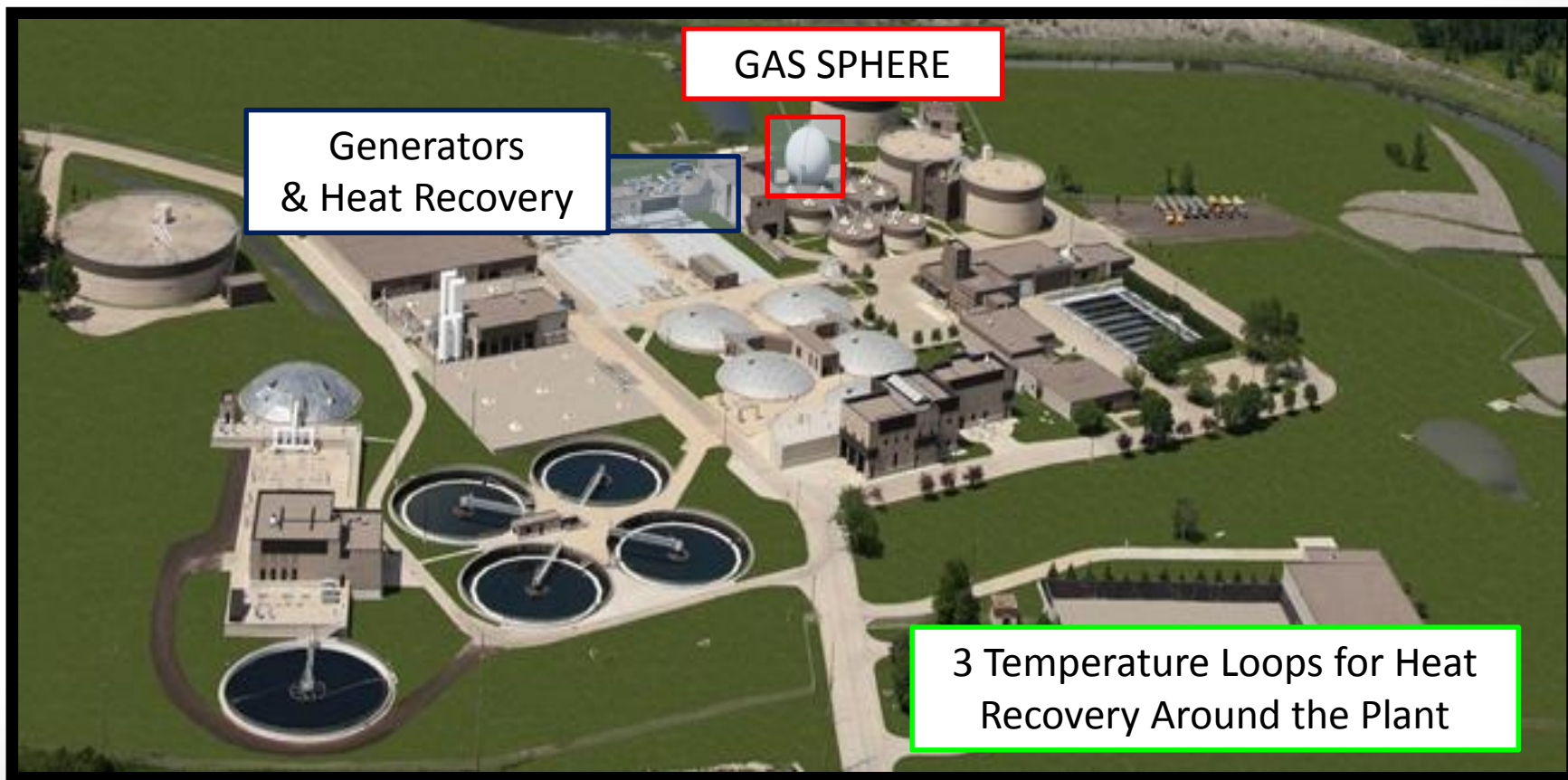
Rochester WRP Facility

Solids Handling



Rochester WRP Facility

Energy Recovery



Aeration

- Water/wastewater consumes 3-4% of all energy
 - Energy = 2%-60% of total operating costs
 - Rochester 20%
 - Aeration = 25-60% of electrical demand.
 - Rochester 46%
- Lots of Different Technologies (but all use energy to provide oxygen for microbiology)
 - Fine Bubble – Ceramic, Membranes (many forms)
 - Course Bubble
 - Jet Aeration
 - Brush / Disc



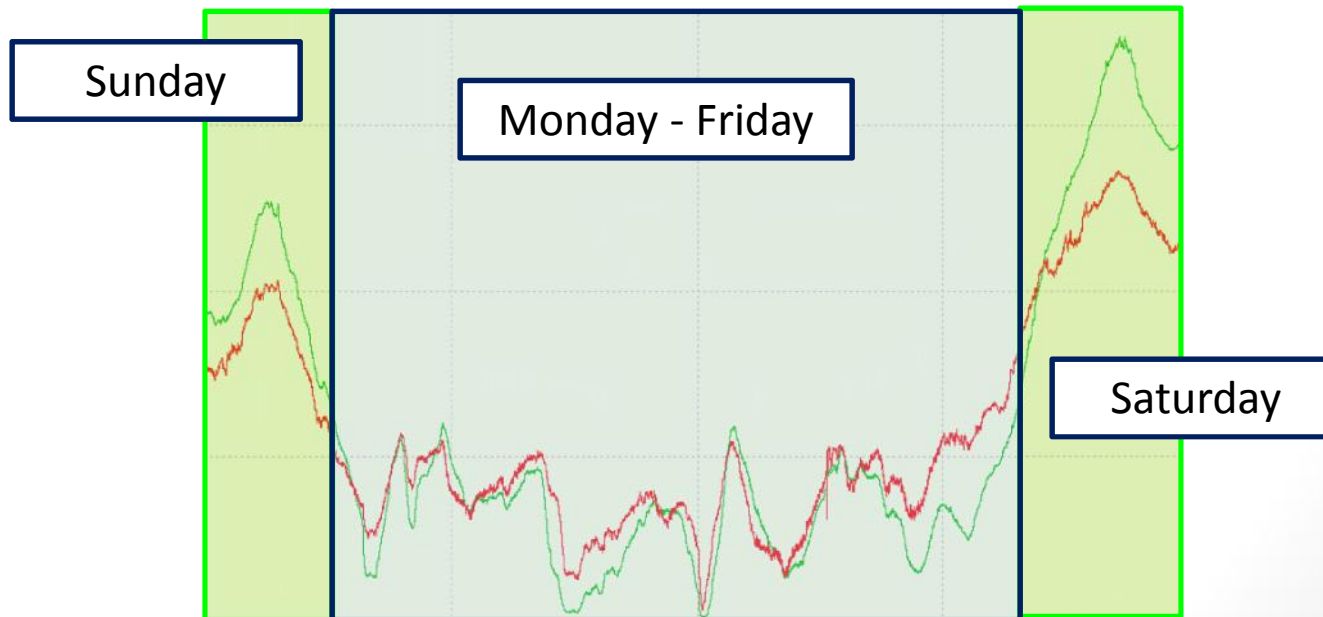
Aeration – Overview

- Microorganism's need to have interaction with oxygen
 - Finer bubbles have more surface area – more location for microorganisms to gain oxygen
 - Rochester – High Purity Oxygen – Surface area of bubble is now 90-95% oxygen vs 21%.
- Tools to monitor aeration
 - DO probes, ORP, BOD/COD, NH₃-N, NO₃-N, Flows



Aeration – Loading

- Flows and loads are NOT constant
 - Understand your loadings
 - Diurnal, Weekly, Seasonally
 - Rochester – Has diurnal, weekly, seasonal (industry, tourism)
 - Adjust flow to meet loading conditions



Aeration – Different Technologies, Same Result

- Activated sludge - DO's higher than 2 mg/L is wasting energy
 - Indicators of low DO environment
 - Presence of low DO filamentous
 - Turbid effluent
 - Dark grey or black sludge (putrid odors)
- Trickling filter – forced ventilation & natural draft
 - Natural draft – uses difference in ambient air temperature and air inside of pores (water temp)
 - Potential for loss of draft if ambient and pore temps are the same
 - Forced air – fans supply oxygen – as little as 0.2 HP/MGal



Aeration – Different Technologies, Same Result

- Oxidation Ditch - generally has different zones
 - Over aeration can affect non-aerated zones
 - May not need all aerator's or can be cycled
- Sequencing Batch Reactors (SBR's)
 - If sequences are based on time intervals may be periods of over aeration (depending on loading)
- High Purity Oxygen (HPO)
 - Easy to overfeed oxygen
 - Difficult adjusting flow



Aeration – Energy for Aerators

Aerator Type	Alpha	DO, mg/L	Avg Eff. Lbs O2/hp-hr
High Speed Surface	0.85	2	1.25
Low Speed Surface	0.85	2	2
Disc Aerator Surface	0.85	2	1.5
Turbine	0.75	2	1.5
Course Bubble Roll	0.65	2	1.4
Course Bubble Grid	0.65	2	1.65
Aspirator w/ Blower	0.6	2	0.5
Aspirator w/o Blower	0.6	2	0.75
Fine Bubble Grid Standard	0.6	2	3.3
Fine Bubble Grid Hi Density	0.6	2	4.6

Source: “Energy Savings through Improved Aeration Efficiency”,
David Redmon, Redmon Engineering Co.

Aeration – What can we do

- Adjust airflows for loading conditions
- Determine if over aerating
- Manage flows where possible
- Understand equipment capabilities
- If you have the capacity/capabilities use the process to your advantage (denitrification)
- Sample / collect data (profile basins)
- Automation
- Upgrade equipment



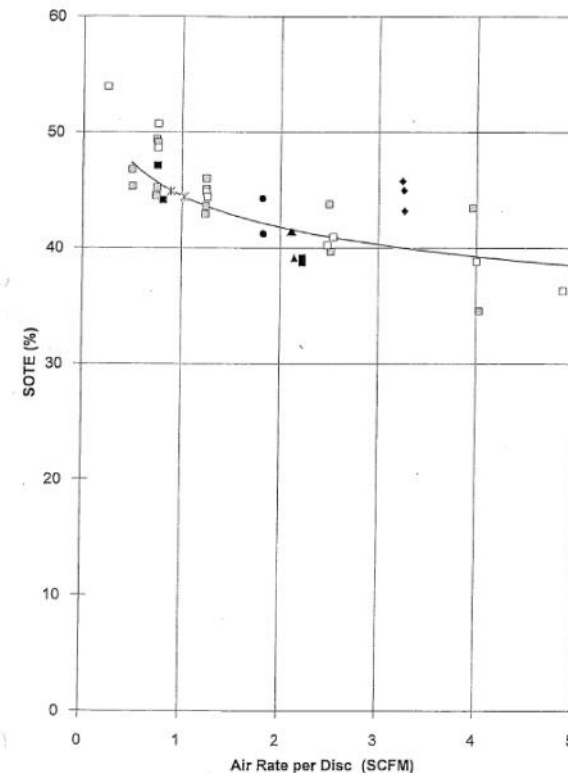
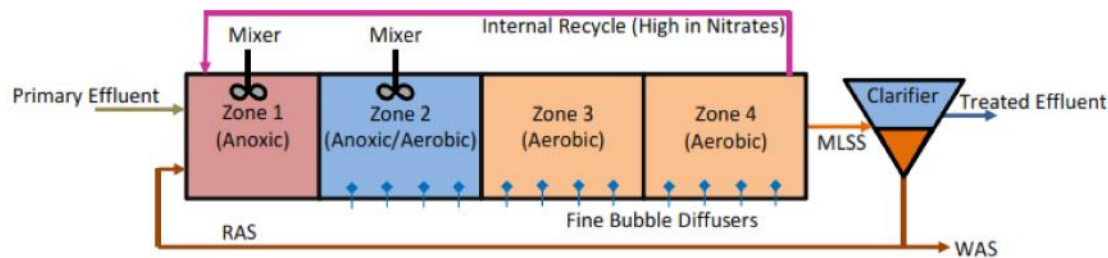
Aeration – Rochester Example

- HPO Plant – Main Air Compressor, 450 HP
 - Treats all flow not to ABC, ability to ramp up O₂ Plant
- ABC Plant – Blowers, 200 HP (1), 600 HP (2)
 - 2013 – AO Process, using 600 HP Blower, 4.5 MGD
 - 2014 – MLE Process, using 200 HP Blower, 2.5 MGD

	Flow, MGD	KW Use	Cost Per Year (\$0.085/KWh)	Total Annual Cost
HPO Plant 2013	10	280	\$208,000	\$431,000
ABC Plant 2013	4.5	300	\$223,000	
HPO Plant 2014	12	320	\$238,000	\$324,000
ABC Plant 2014	2.5	115	\$86,000	

Aeration – Rochester Example

- Switching to MLE allows use of $\text{NO}_3\text{-N}$ as O_2 Source
 - Oxygen equivalent of nitrate is $2.86 \text{ g O}_2 / \text{g NO}_3\text{-N}$.



- Using the smaller blower reduces SCFM/pod which in turn increases your oxygen transfer efficiency
 - 4 SCFM / pod = 38% SOTE
 - 2 SCFM / pod = 43% SOTE

Aeration – Metropolitan Wastewater Treatment Plant, St. Paul Case Study

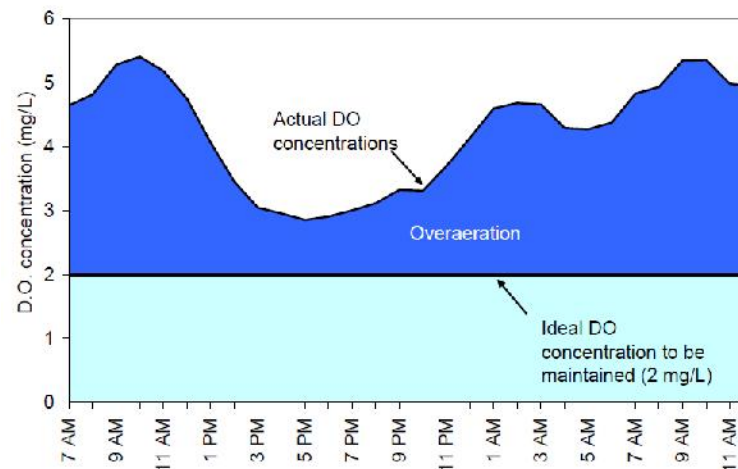
- Identified diffuser fouling
- Investigated cleaning techniques
 - Found high pressure/chemical method works the best
- Performed the work internally
- Energy savings of 22%
- Payback 3 months



Source: <http://www.airbestpractices.com/industries/wastewater/aeration-energy-offers-opportunities-save>

Aeration – Case Study, Aeration Control using DO Monitoring

- Oxidation Ditch - 2.5 MGD, Disc Aerators
- Diurnal loading significant (50-240- lbs O₂/hr)
- Operators manually tried to adjust disc aerators but found difficult to match demand
- Installed online O₂ Monitoring and VFD's.
- 23% Reduction in Electrical Demand



Source: Proceedings of WEF, WEFTEC 2005, Session 11-20, pp. 1617-1629(13), "Aeration Control Using Continuous Dissolved Oxygen Monitoring in an Activated Sludge Wastewater Process", David Phillips.

Chemical Use in Wastewater

- Used at most wastewater treatment plants
 - Chemical use can vary significantly in operating costs
 - Rochester - 10% of Operating Budget
- Major uses of chemicals in wastewater
 - Disinfection (Rochester – Chlorine, Sodium Bisulfite)
 - pH Buffering
 - Oxidation
 - Precipitation (Rochester - Ferric, Alum)
 - Coagulation (Rochester – Polymer)
 - Others – Scale Control, Odors, Stabilization, etc.



Chemical – What to Consider

- Understand what you are using the chemicals for
 - Find out how much you should be applying
 - Measure the success of the chemicals
 - Analysis of chemicals
 - Measure $\text{PO}_4\text{-P}$ for Alum Addition, etc.
 - Measure application rates / capture rates for polymer use, etc.
- Ways to measure chemical use
 - Measure tank volumes and use pumps/flow meters
- Calibrate the equipment
 - Equipment needs to be calibrated on regular intervals
- You have options for chemical suppliers



Chemical – Rochester Examples

- Sodium Bisulfite – Feed Rate Evaluation
 - Previous personal had determined dosing rates and in SCADA had included a “gain” factor.
 - Performed basic calculations and determined that a Factor of Safety (FS) of over 7 was being used.
 - Adjusted FS to 4 – 75 gpd – 50 gpd
 - Annual Savings = \$17,500



Chemical – Rochester Examples

- Polymer – Evaluation of Chemical Suppliers
 - GBT's are used to thicken both WAS and digested sludge
 - Both polymer suppliers provided the opportunity to test their polymer's bench scale
 - Based on bench scale results test full scale for 1 tote.
 - Polymer supplier 2 couldn't find polymer for digested
 - Annual savings projected = \$27,500, Realized = \$14,000

Results for WAS	Polymer Application	Solids off GBT	Cost / Ton During Trial	Long Term Results
Polymer Supplier 1	6.3 lbs/ton	5.1%	\$12.93/ton	\$15.96/ton
Polymer Supplier 2	8.7 lbs/ton	4.9%	\$19.05/ton	\$19.06/ton

Chemical – Case Study, Kiel, WI

- Ferrous Sulfate – Online analyzer
 - Chemical precipitate to limit of 1 mg/L P
 - Cheese making industry in town that contributed significant loads of P that was variable
 - Added a single point (secondary clarification) online ortho-phosphate analyzer
 - Analyzer connect to SCADA for feedback control of the feed pumps.
 - Chemical reduction of 20% since installation.



Source: Proceedings of WEAO Technical Conference, Ottawa Ontario 2012 “Using online Analyzer for Optimizing Chemical Phosphorous Removal Process in Municipal Wastewater Treatment”, Wei Zhang, David Roskowic.

Mixing in Wastewater

- Provide homogenous mixture
- Mixing can be mechanical, hydraulic, pneumatic
- Numerous Locations
 - Aeration Basins
 - Digesters
 - Chemicals
 - Storage Tanks
 - Blend Tanks



Mixers – What to Consider

- Typical Design – Varies by mixing technology
 - Mechanical liquid train = 1 hp / 1000 ft³
 - Mechanical digester mixer = 0.3 hp / 1000 ft³
- Over mixing wastes energy / negatively affect process
- Under mixing wastes resources / tank volume
- Mixing depth and position matter



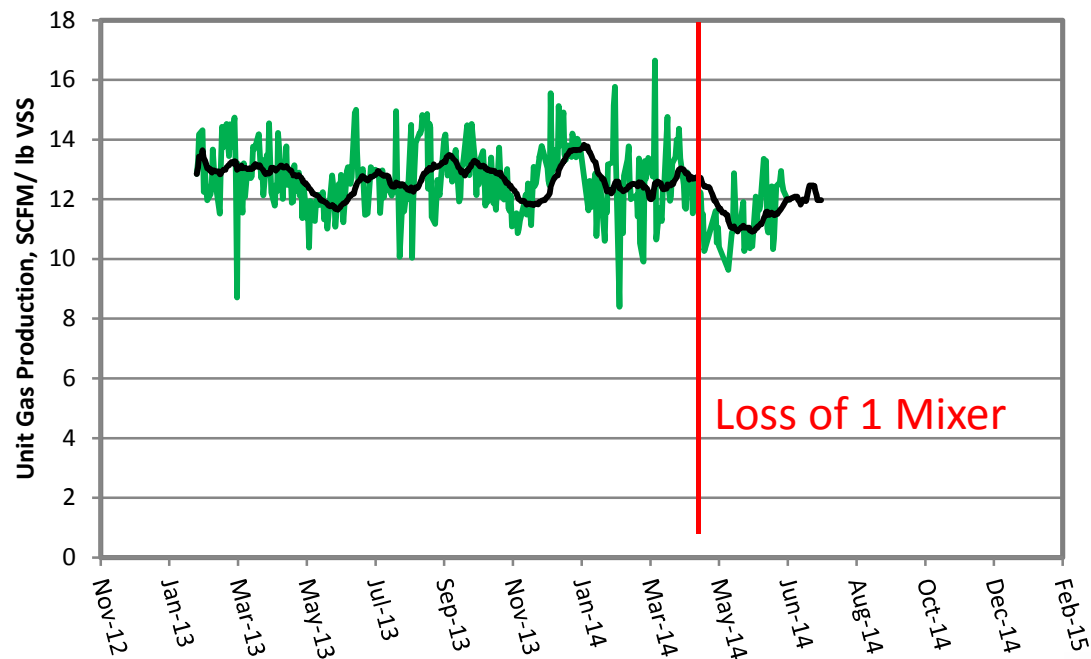
Mixers – Rochester Example

- Anaerobic Digesters – Gas Piston (cannon) Mixing
- 1.85 Mgal each
- 10 Cannons per Digester
- 40 Hp Gas Mix Compressor / Digester
- Beginning of May, lost one gas mixer
- 5 Canons used in each digester
- One mixer for both digesters



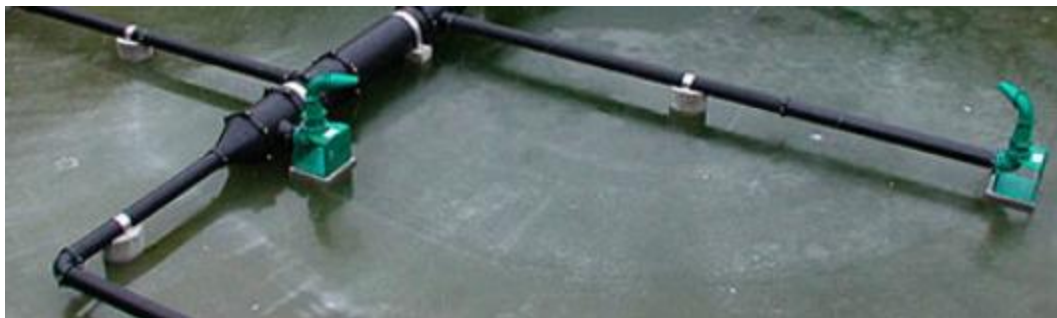
Mixers – Rochester Example

- No substantial loss in gas production.
- With 2 Mixers = 12.7 SCF / lb VSS; 57% VS dest
- With 1 Mixer = 11.5 SCF / lb VSS; 61% VS dest.
- 10% Reduction in gas with 50% reduction in energy



Mixers – Moorhead Example

- Anaerobic digesters
- Jet mix system
- Designed to run 24/7
- Run several hours a day, 3 days a week
- Any decreased gas production offset by not running the system continually
- Still meeting VS destruction limits



Source: Andy Bradshaw, City of Moorhead

Mixers – Greeley CO Case Study

- 14.7 MGD Plant with dewatering centrifuges
- Sudden dramatic loss in performance
- 500 gallon tank to mix liquid coagulant polymer with water.
- High speed mixing followed by aging 0.5 hours.
- Extended high speed mixing found to fracturing the polymer chains
- Improper low shear mixing
- Installed new mixing chamber deliver device
- Reduction in Polymer saved \$12,000 / yr

Source: “In-Line Polymer Preparation & Feed Boosts Dewatering Performance”, Steve Hettinger, http://prominent.us/promx/pdf/greeley_colorado_article_final2.pdf

Solids production in Wastewater

- Byproduct of all wastewater treatment plants
- Generated at numerous places throughout the plant
 - Primary sludge
 - WAS
 - Tertiary sludge
 - Scum / grease
 - Screenings
 - Grit
 - Biosolids



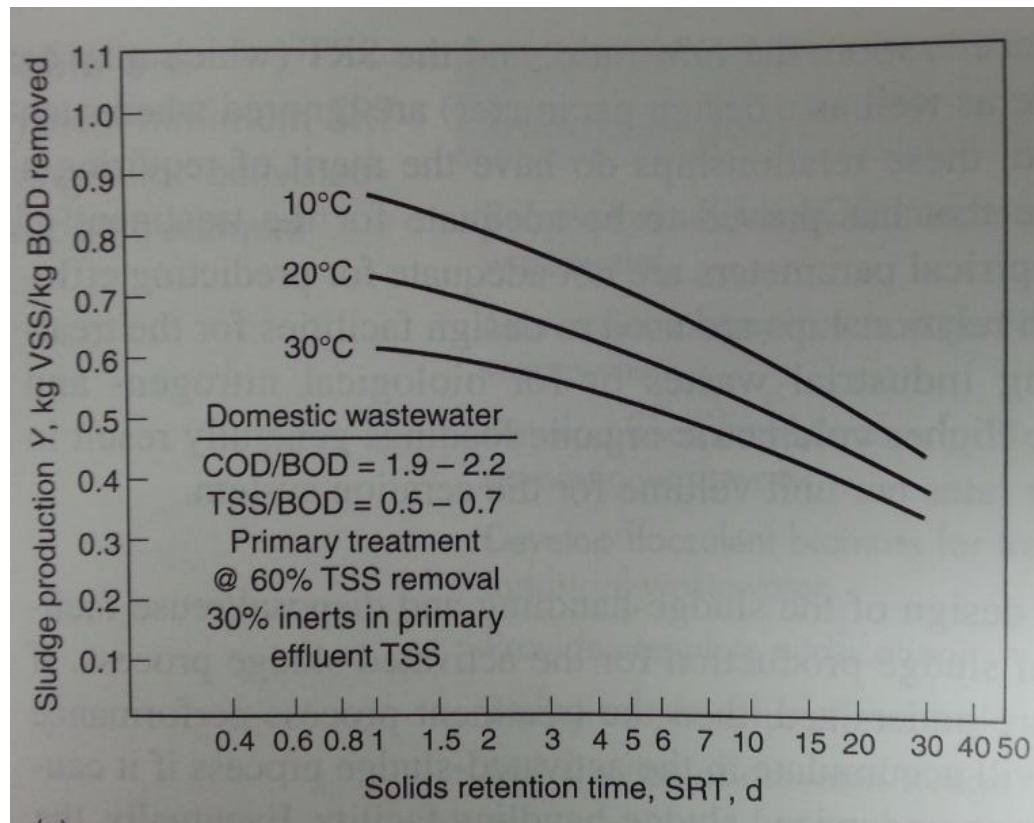
Solids – What to Consider

- Solids Generation
 - Can you make any changes in your operation
- Volume of Solids
 - How are solids dewatered / storage
- Conveyance of solids
 - Pumps, conveyors, augurs, etc.
- Protection of Equipment
 - Screens, grit removal
- Nutrients movement
 - Ammonia, Nitrogen, Phosphorous



Solids Production - Rochester

- Yield decrease with higher SRT and higher temps
- Yield decreases due to endogenous respiration



Solids Production - Rochester

- Solids Production 2013

	Yield lb VSS/lb BOD	SRT Days
HPO	0.76	1.5
ABC	0.35	15.4

- Consider the effect of previous aeration adjustments

	Flow MGD	PE BOD lbs/day	WAS Production lbs VSS/day	Gas Production SCFM
HPO Old	10.0	16,300	12,400	109
HPO New	12.0	19,500	14,800	131
ABC Old	4.5	7,300	2,600	23
ABC New	2.5	4,000	1,400	12
Old Strategy Sludge Production			15,000	132
New Strategy Sludge Production			16,200	143

- Increased solids / gas production by 8%

Solids - Chemical Enhanced Primary Treatment - Rochester

- Rochester – CEPT started in late 80's.
 - 40% BOD removal 2013
 - 60% TSS removal 2013
- Average Ferric Use 480 gpd =35 gal/Mgal (37%)
 - 0.25 mol Fe / mol P
- Average cost is about \$480 /day
- Average savings in Aeration \$140/day

	BOD Removal %	Primary Effluent BOD, ppd	Increase in O2 Demand, ppd
With CEPT	40	24,000	6,600
Without CEPT	25	30,000	

Solids – Gravity Thickener & Digester Upsets – Case Study

- Primary and WAS co-thickened in gravity thickener
- Large variations in gravity thickener performance
 - Solids varied from 4-8%
- Gravity thickener also acted as fermenter
 - Variable VFA load to digester
- Inconsistent load led to digester upset / foaming
- Better control of feed
- Increase gas production



Source: Proceedings of WEF, WEFTEC 2006, “Design and Operational Considerations to Avoid Excess Anaerobic Digester Foaming”, Neil Massart.

Sidestreams in Wastewater

- Sidestream – any flow from a solid treatment that is returned to the liquid process
 - Filtrate from a GBT
 - Overflow from a gravity thickener
 - Centrate from a centrifuge
 - Dewatering of sludge storage
 - Filter backwash
- Often not sampled and considered insignificant
- Often can be nutrient rich
- Large plants starting to incorporate sidestream treatment.



Sidestreams what to Consider

- Sampling – what is the impact
 - Must consider loads (not just flow)
- Is it a continually or intermitted flow
- What is the source, can it minimized
- Is there any equalization
- Is treatment possible
- Any possible uses for an advantage



Sidestreams Impact - Rochester

- Sidestream 2013 – GBT Filtrate (Dig and WAS)
 - BOD – 1,620 ppd = 4% of Influent Load
 - TSS – 5,400 ppd = 18% of Influent
 - Phosphorous – 270 ppd = 26% of Influent
 - Ammonia – 1,660 ppd = 35% of Influent
 - O₂ Demand 7,600 ppd = 2.5 MGD Influent (325 mg/L BOD)
- Ammonia, Phosphorous largely from digested sludge
- Potential to reduce P by increase GBT capture rate
- Sidestream treatment in future???

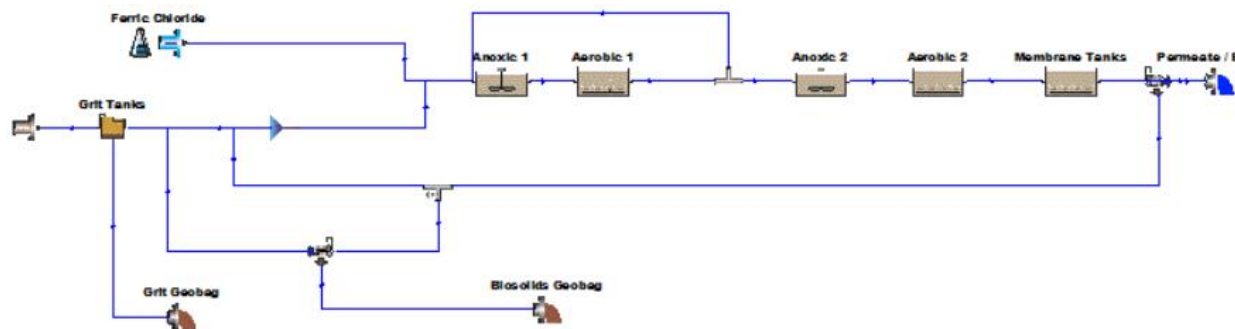
Why treat in a Sidestream

- Higher safety of factor for nitrification and biological phosphorous removal
- Reduce load on process and can remove to a lower level
- Delay plant expansion
- Concentrated load / higher temps = faster kinetics = smaller tank sizer
- Can use existing infrastructure



Case Study - Sidestream Treatment Potential

- Evaluation for sidestream treatment
- Plant with 5 stage Bardenpho BNR Process with Anaerobic Digestion
 - Nitrogen accounts for 15-20% of influent
 - Phosphorous accounts for 20-30% of influent
- Big picture results – biowin modeling



Sidestream Treatment Potential

- Comparison of Mainstream vs Sidestream

Table 3: Cost to Remove a Pound of Nitrogen in Mainstream

Category/Parameter	Units	5-stage BNR + Denitrification Filters	
Plant		Plant A	Plant B
Cost per pound TN removed (capital)	\$/lb	\$0.90	\$1.63
Cost per pound TN removed (O&M)	\$/lb	\$1.76	\$1.68
Total	\$/lb	\$2.66	\$3.31

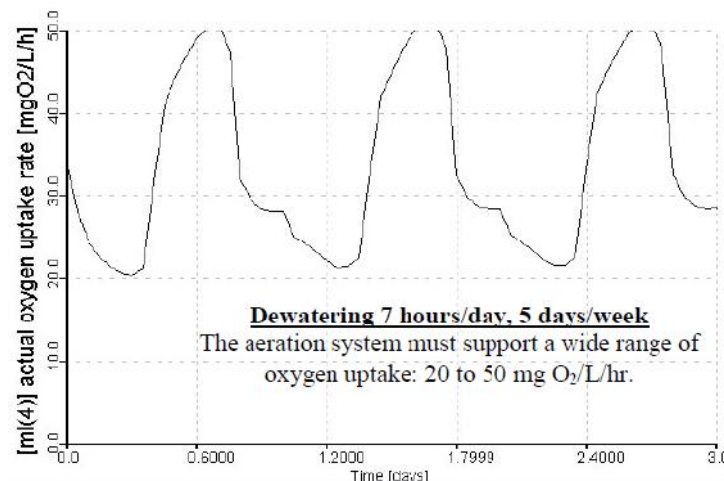
Table 4: Cost to Remove a Pound of Nitrogen in Sidestream

Category/Parameter	Units	Nitrification/ Deammonification		Nitrification/ Denitrification		Bioaugmentation	
Plant		Plant A	Plant B	Plant A	Plant B	Plant A	Plant B
Cost per pound TN removed (capital)	\$/lb	\$0.54	\$0.74	\$0.45	\$0.60	\$0.29	\$0.82
Cost per pound TN removed (O&M)	\$/lb	\$0.39		\$1.04		\$1.32	
Total	\$/lb	\$0.93	\$1.13	\$1.49	\$1.65	\$1.61	\$2.14

Source: "Process and economic Benefits of sidestream Treatment" Katya Bilyk.
http://info.ncsafewater.org/Shared%20Documents/Web%20Site%20Documents/Annual%20Conference/AC%202011%20Papers/WW_T.am_10.15_Bilyk.pdf

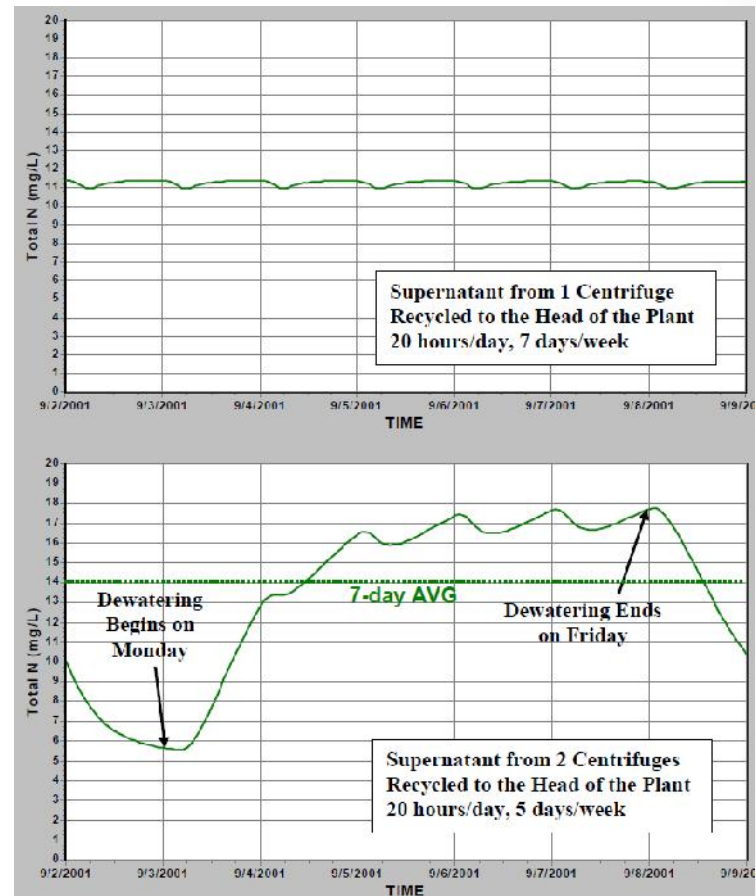
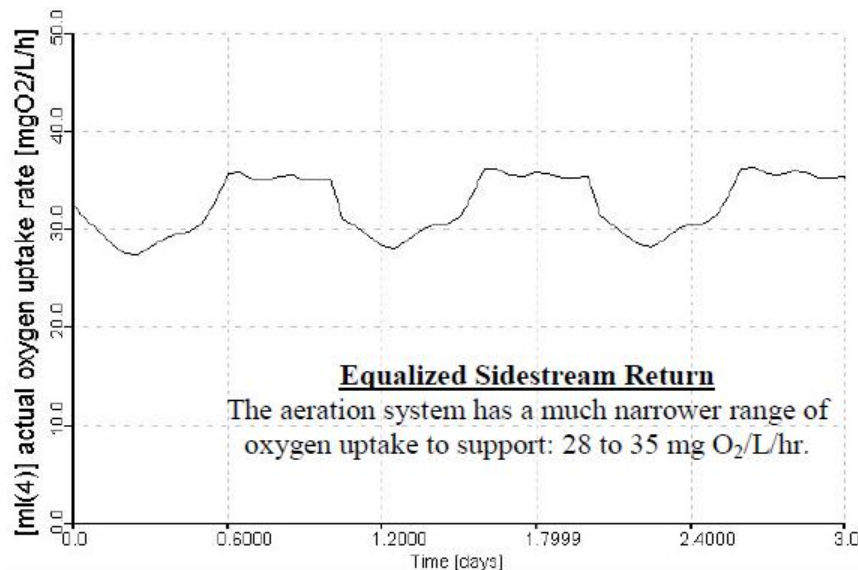
Sidestream - Equalization Case Study

- Small 2 Stage BNR plant with Centrifuges
 - Centrifuges operated 7 hrs/day 5 days/week
- Periods of low DO's
- Filaments formed in MLSS
- Effect of equalization on oxygen demand
- Altered dewatering schedule



Sidestream - Equalization Example

- Effect on effluent TN with 2 different EQ strategies



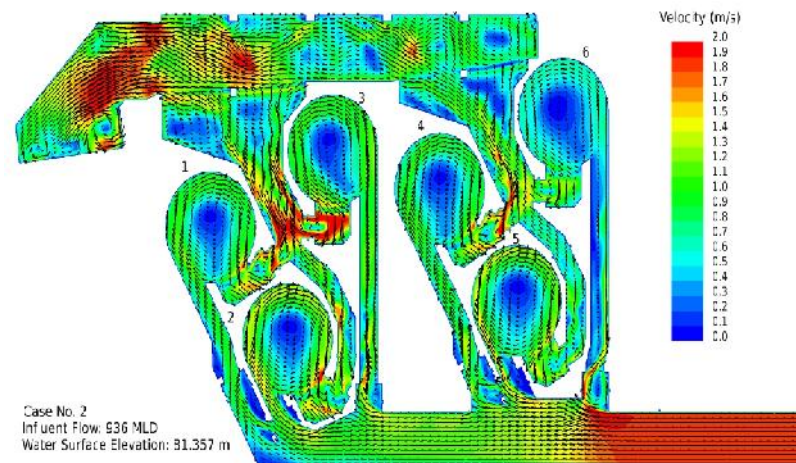
Source: Proceedings of WEF, WEFTEC 2006, "Nitrogen and Phosphorous-Rich Sidestreams: Managing the Nutrient Merry-Go-Round", Heather Phillips.

Big Picture for Process Efficiency

- Understand your plant
- Understand your loads and where they come from
- Optimize means adjusting controls to what is needed not the worst case
- Equalize whenever possible – cruise control
- Collect data - SCADA
- Make changes one at a time where possible
- Its ok to try new things – everything has a cause and effect

Optimization - Modeling

- Wastewater Treatment Process Simulators
 - Calibration is key to successful modeling
 - Biowin
 - GBS-X
- Fluid Dynamic Modeling
 - CFD = Computational Fluid Dynamics
 - ANSYS Fluent
 - FieldView



Questions

